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Prediction of the optimal start technique in ski cross using musculoskeletal optimization

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Introduction: Ski cross is a relatively new winter sport that was on the Olympic program for the first time in Vancouver 2010. In ski cross four skiers compete against each other on a special ski cross course which consists of different obstacles including several types of jumps and turns. It is typically the skier with the best start taking the lead down the course, which enables the skier to choose the ideal line through the course and thereby control the race. Therefore, the aim of this study was to optimize the skier's start technique using an optimization study in the AnyBody Modeling System.

Methods: A four meter high and 16 meter long start ramp covered with artificial snow track (Skitrax FA, Skitrax World – ODCC GmbH, Oberaudorf, Germany) was built for the experiment. Kinematic data were collected from 56 soft reflective markers placed on anatomical landmarks and the start gate with a 12-camera motion capture system (Qualisys AB, Gothenburg, Sweden) and a sampling rate of 236 Hz. A former Olympic skier (height: 172 cm, weight: 92 kg) from Sweden participated in the study where he performed one start with full effort. The kinematic data were used as input to drive a Ski Cross Model in the AnyBody Modeling System (Anybody Technology, Aalborg, Denmark). Boundary conditions were applied to the model: A spherical joint between the skier's hands and handles to control the position of the hands throughout the start. A kinematic "measure" was applied to drive the vertical position of the feet/skis. The objective function in the optimization study (AnyOptStudy) was to optimize the horizontal centre of mass velocity using a feasible direction search algorithm. The optimization model was restricted to have a maximal muscle activity below 100%. The following parameters were optimized: knee-, hip-, shoulder-, elbow-angle in the sagittal plane and the foot/ski-snow contact position in respect to time.

Results and Discussion: The skier's horizontal velocity at release was improved by approximately 1.5 m/s. The results showed that a greater knee/hip flexion and lowering the center-of-mass position is preferred at gate drop (see figure 1). Larger/increased range of motion in the shoulder and delayed elbow flexion shows that the skier is making a prominent pull with his arms prior to release. The elbow flexion pulls the model forward in the direction of the slope.

Conclusion: The results from this optimization are most likely not the final solution, but it can serve as a guideline on how a better starting technique can be obtained. Furthermore, the results from this study show that computer optimization can be used to predict new movement patterns of complex movements.

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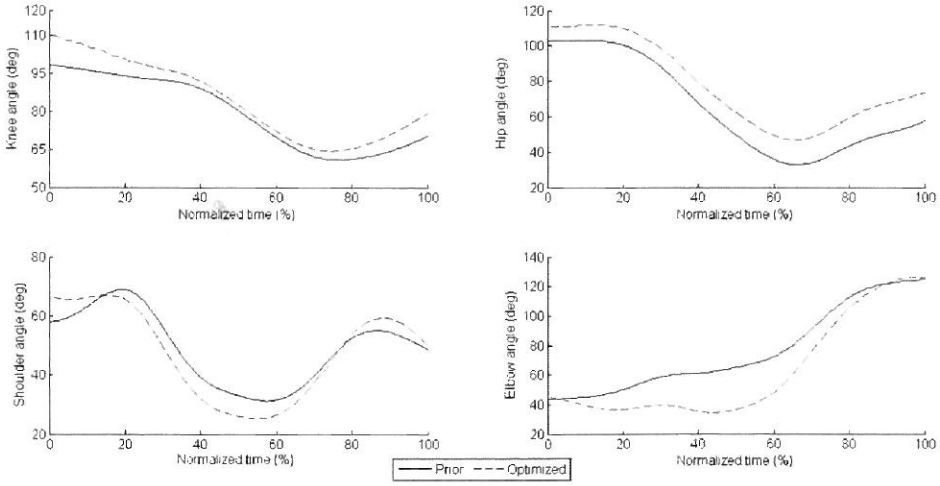

Figure 1: Illustration of the knee (A), hip (B), shoulder (C) and elbow angle (D) from the experimental data and the optimization data from gate drop (0 %) to release (100 %).